Sea Ice Mechanics

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Research Focus

New Sea-Ice Constitutive Model

- Elastic-Decohesive Model

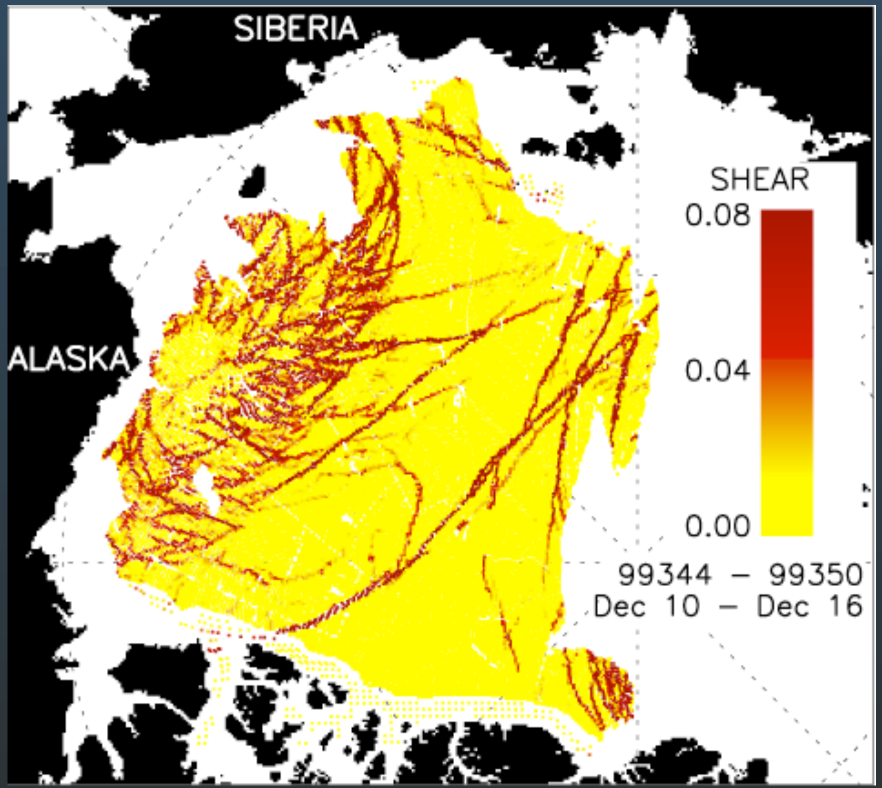
Numerical Method

- Material-Point Method

Why A New Ice Model?

The viscous-plastic model is an isotropic model based on a 100 km scale in which it was assumed that cracks, ridges and leads were randomly distributed.

RGPS analysis of satellite images shows large ice deformation events occurring in long-lasting linear features that appear to correspond to displacement (or velocity)discontinuities in the deformation field due to leads.



Elastic-Decohesive Sea Ice Model

Overall Objective: Numerically simulate "linear kinematic features" (eg. leads and ridges)

Initial Focus: Prediction and appearance of leads

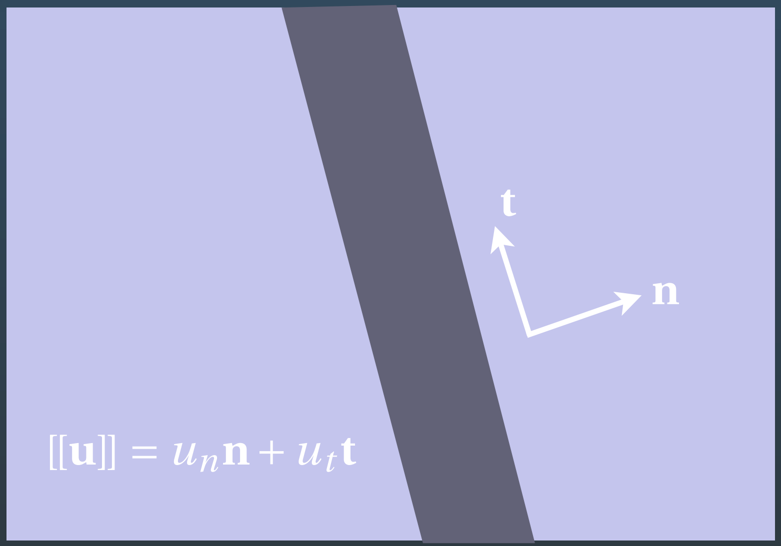
Proposed Approach: Elastic-Decohesive Model

For thick first-year ice and multi-year ice, we assume most deformation occurs due to discontinuities in the displacement field.

Ice is quasibrittle so we can borrow from models of concrete and rock.

Elastic-Decohesive Model

- Intact ice modeled as elastic
- Leads modeled as discontinuities
- Model predicts initiation of a lead and its orientation
- Traction is reduced with lead opening until a complete fracture forms
- Implementation similar to elastic-plastic model



Schreyer, H., L. Monday, D. Sulsky, M. Coon, R. Kwok (2006), Elastic-decohesive Constitutive Model for Sea Ice, J. of Geophys. Res., 111, C11S26, doi:10.1029/2005JC003334.

Simulate a Region of the Beaufort

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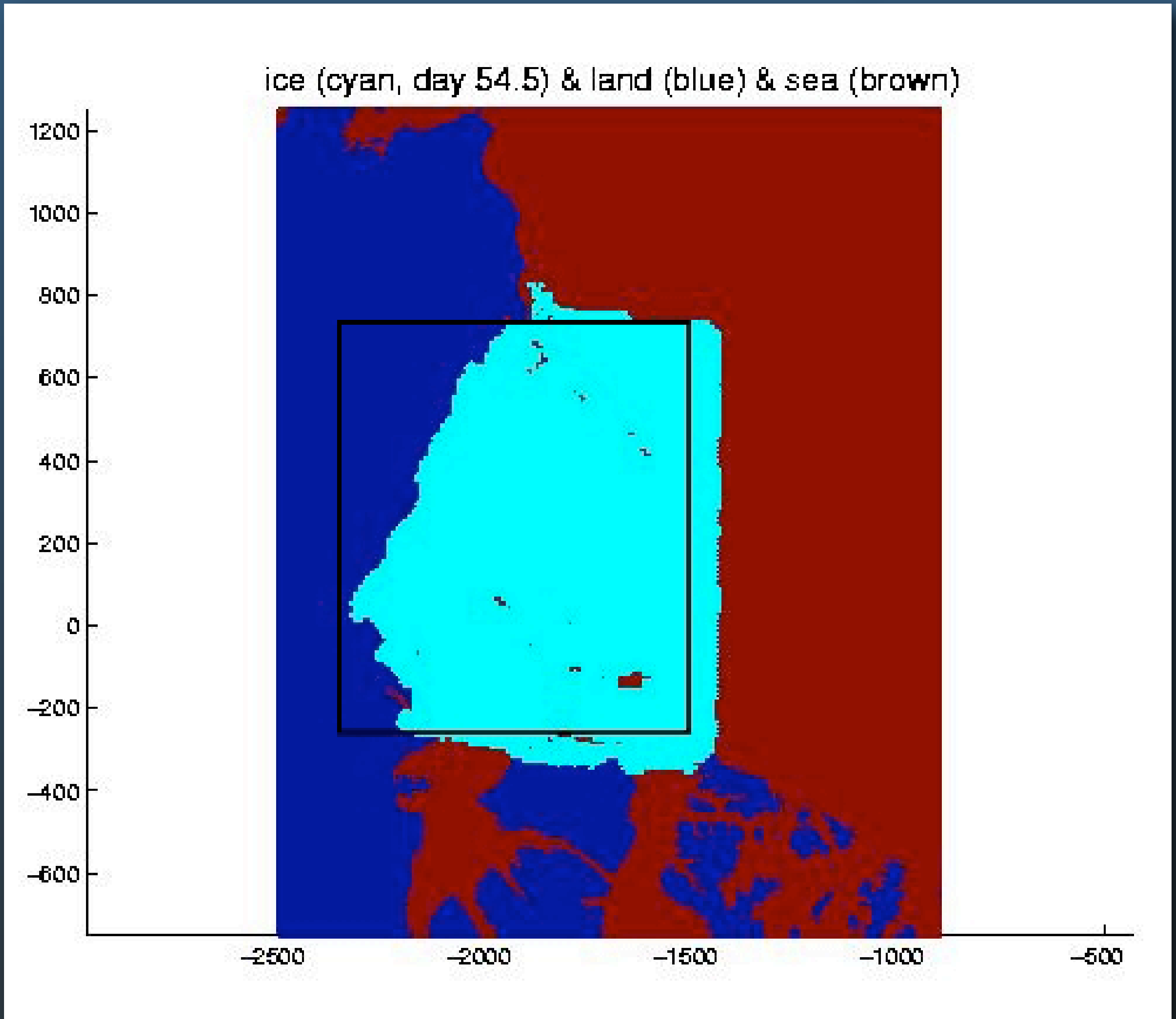
Problem Set Up

Simulate 16 days in Feb/Mar, 2004



$E = 1$ MPa

$\nu = 0.36$

$\tau_{nf} = 25$ KPa

$\tau_{sf} = 15$ KPa

$f'_c = 125$ KPa

$u_0 = 400$ m

$s_m = 4$

Apply known winds and ocean currents from a model.

Material-Point Method

Solves standard momentum equation

$$(\rho h)\frac{d\mathbf{v}}{dt} - \mathbf{t}_a - \mathbf{t}_w + (\rho h) f_c (\mathbf{e}_3 \times \mathbf{v}) - \nabla \cdot (\boldsymbol{\sigma} h) = 0$$

Inertia Coriolis Stress div

Air Drag:

$$\mathbf{t}_a = c_a \rho_a \|\mathbf{v}_a\| \mathbf{R}_a \mathbf{v}_a \qquad \mathbf{R}_a = \begin{bmatrix} \cos\alpha & -\sin\alpha \\ \sin\alpha & \cos\alpha \end{bmatrix}$$

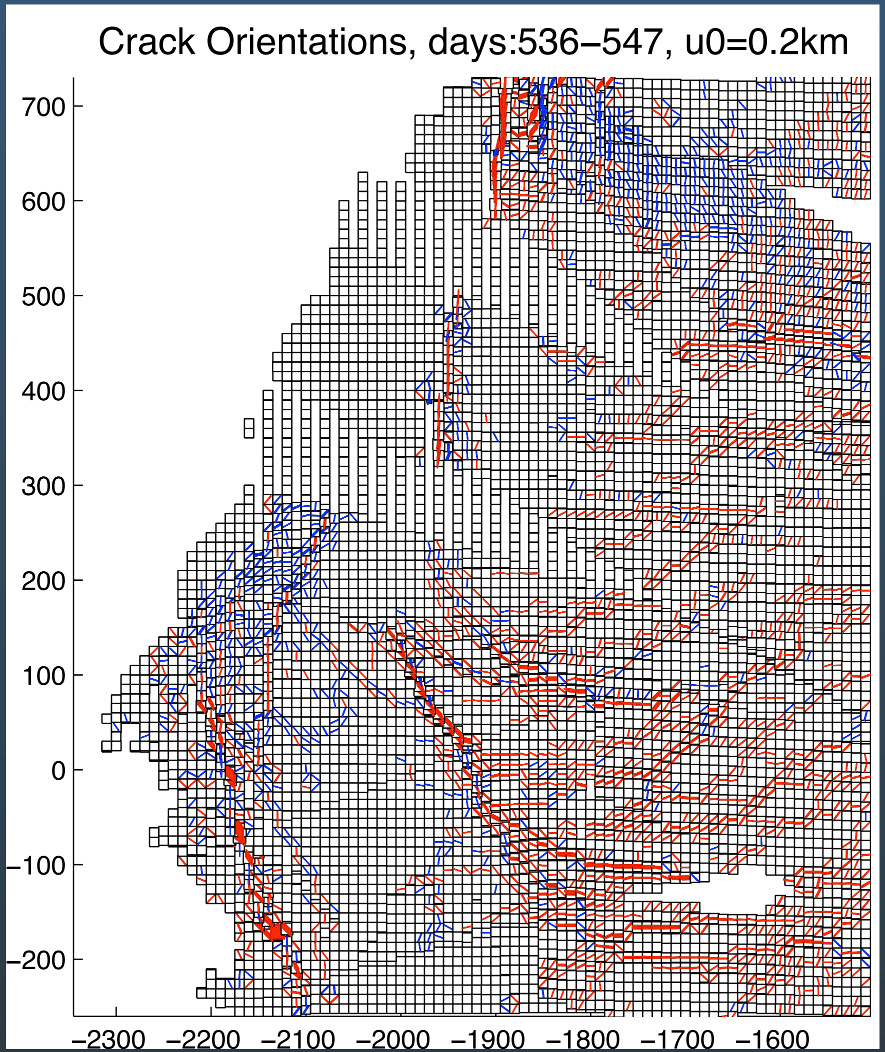
Water Drag:

$$\mathbf{t}_w = c_w \rho_w \|\mathbf{v} - \mathbf{v}_w\| \mathbf{R}_w (\mathbf{v} - \mathbf{v}_w) \qquad \mathbf{R}_w = \begin{bmatrix} \cos\beta & -\sin\beta \\ \sin\beta & \cos\beta \end{bmatrix}$$

Plus ice thickness distrubution and Bitz-Lipscomb thermodynamics

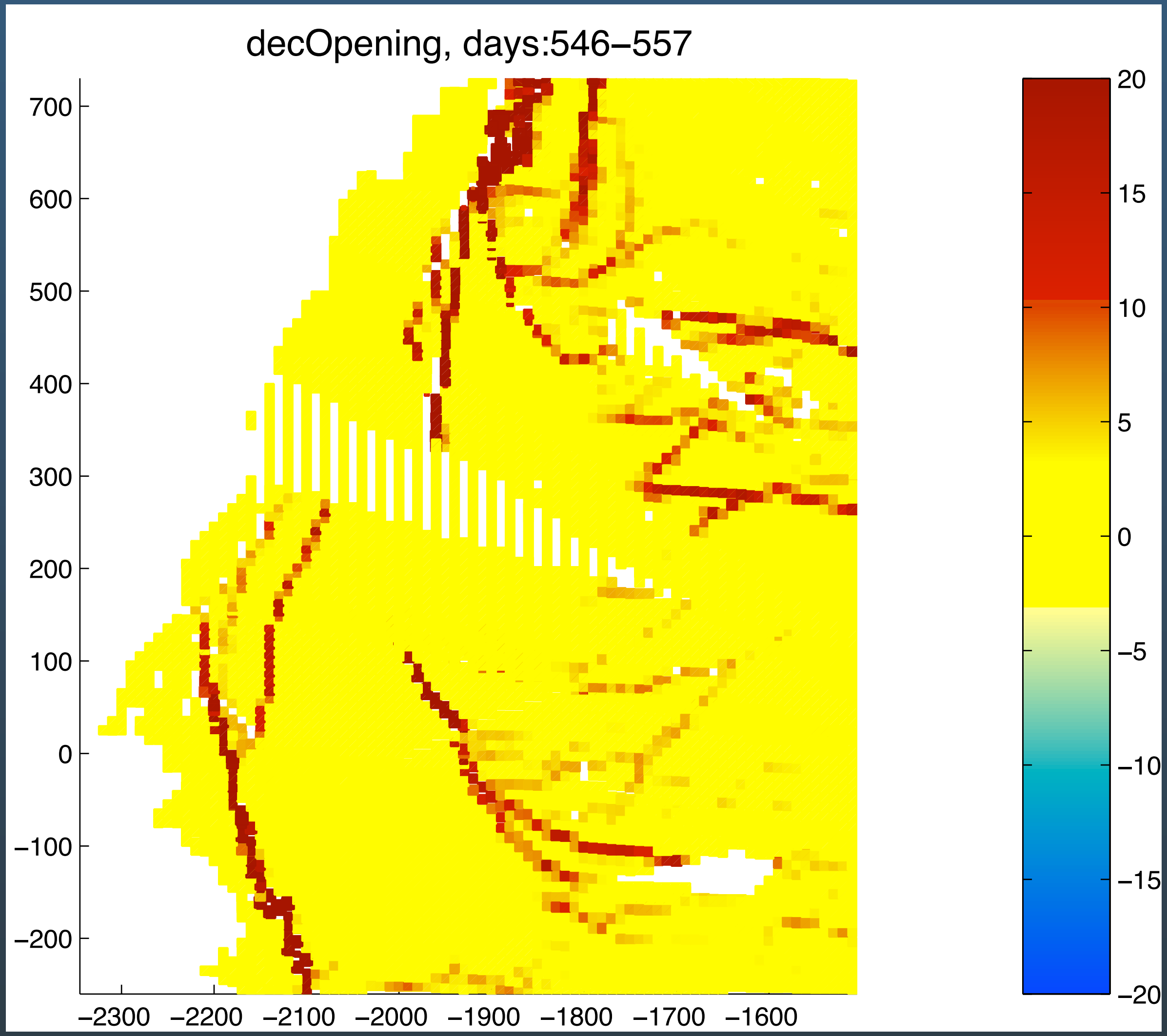
Initialization

Where are existing leads?

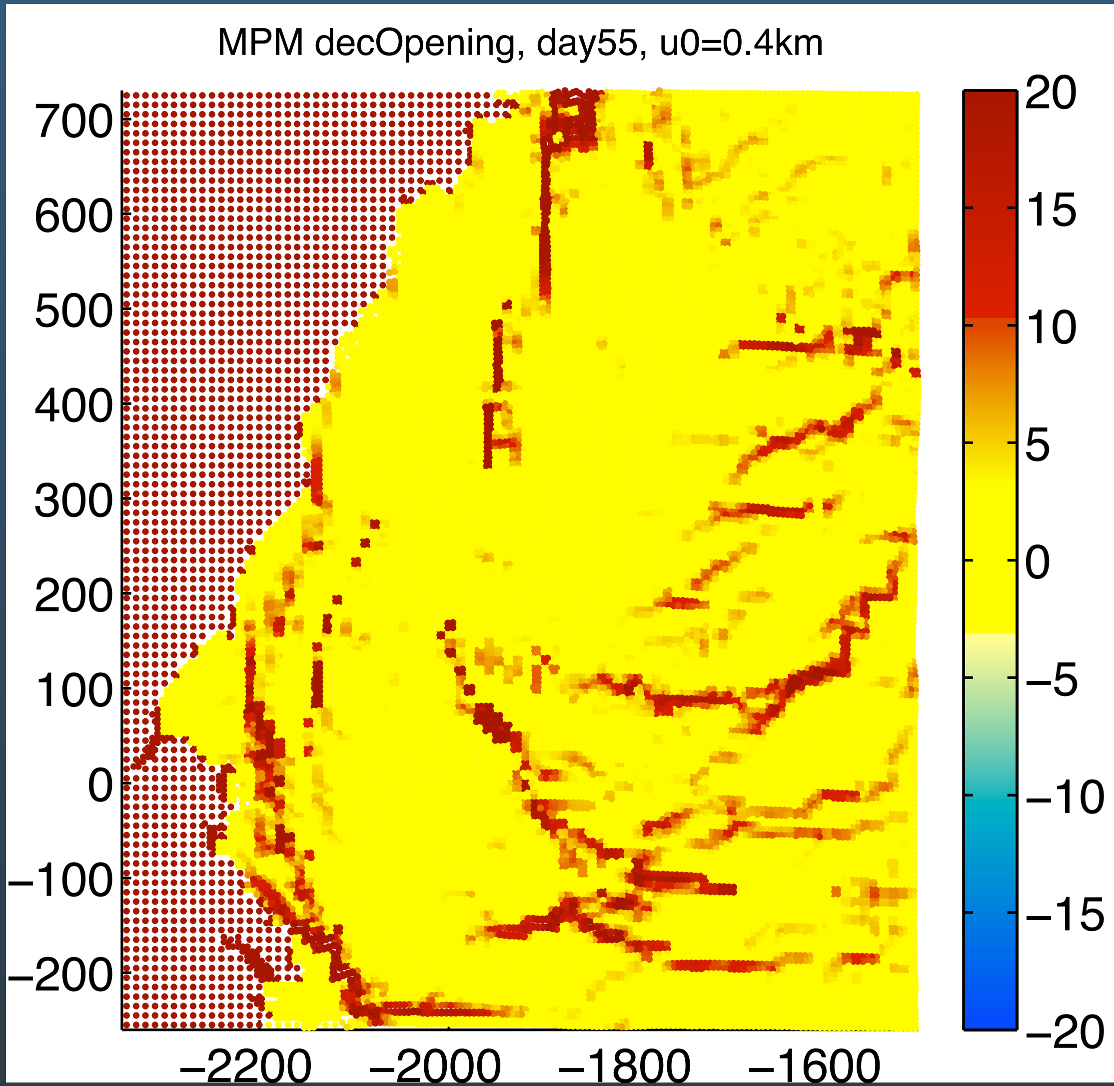


Fracture Patterns in the Beaufort

day 55



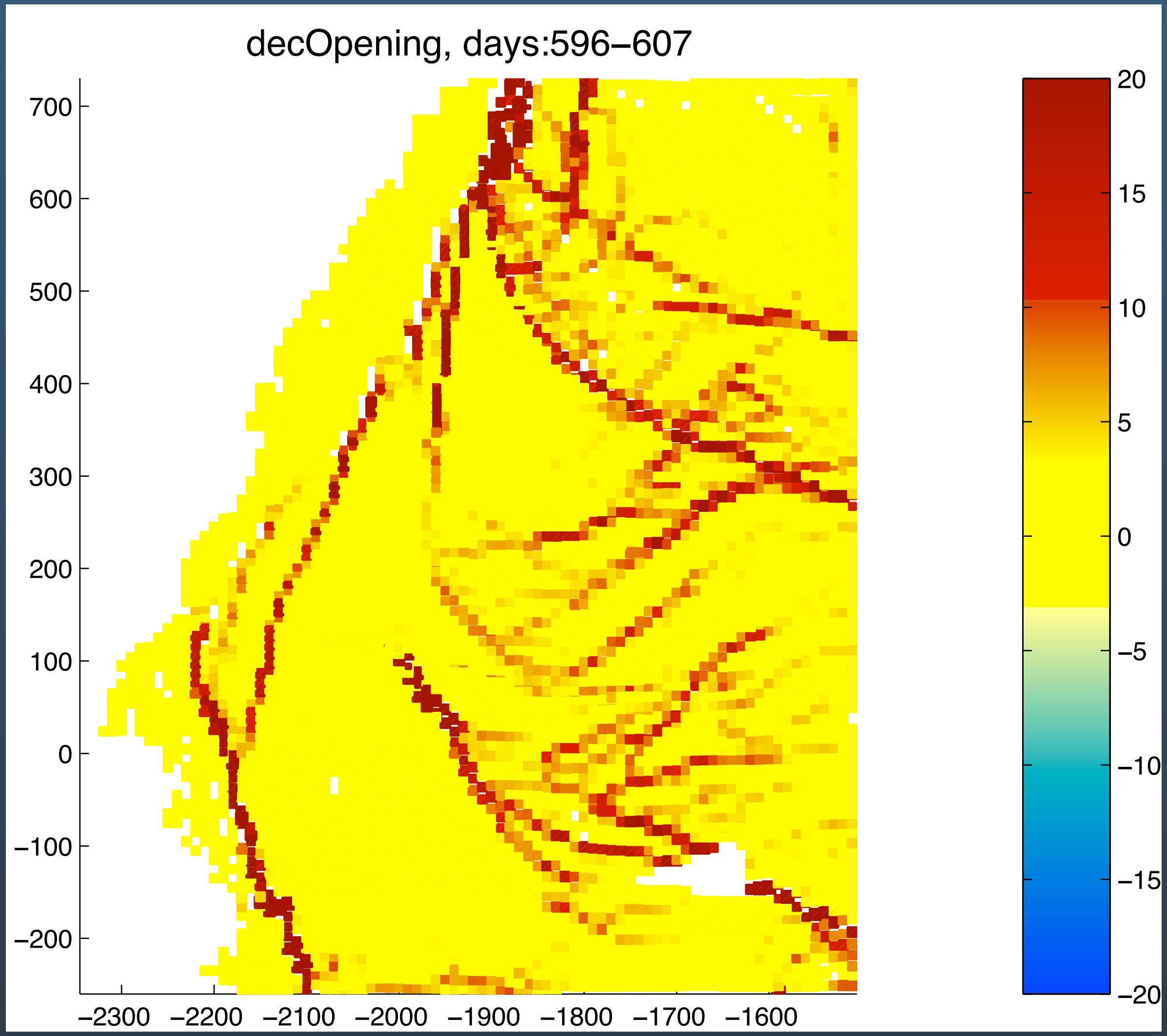
Observation



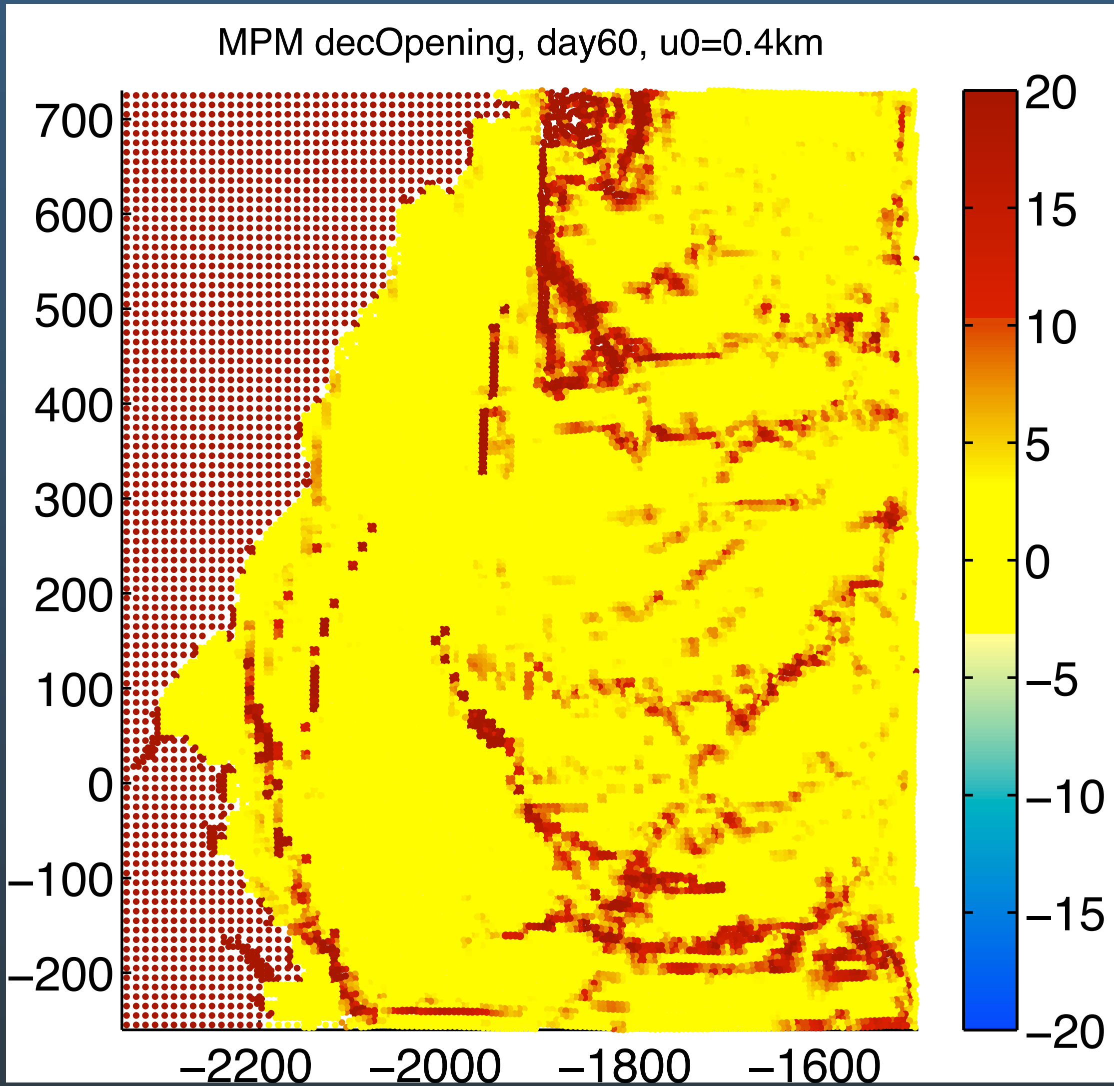
Simulation

Fracture Patterns in the Beaufort

day 60



Observation



Simulation

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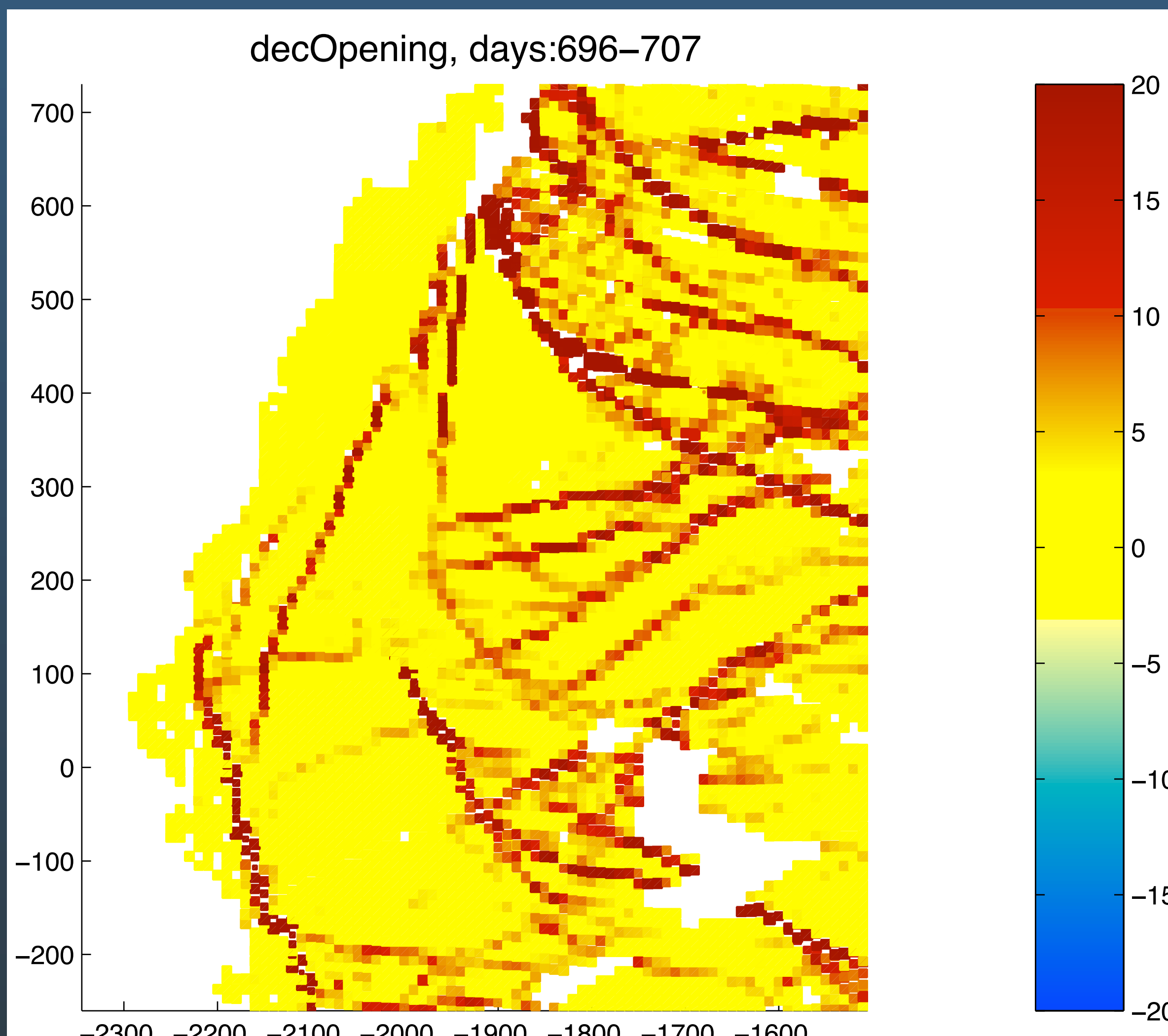
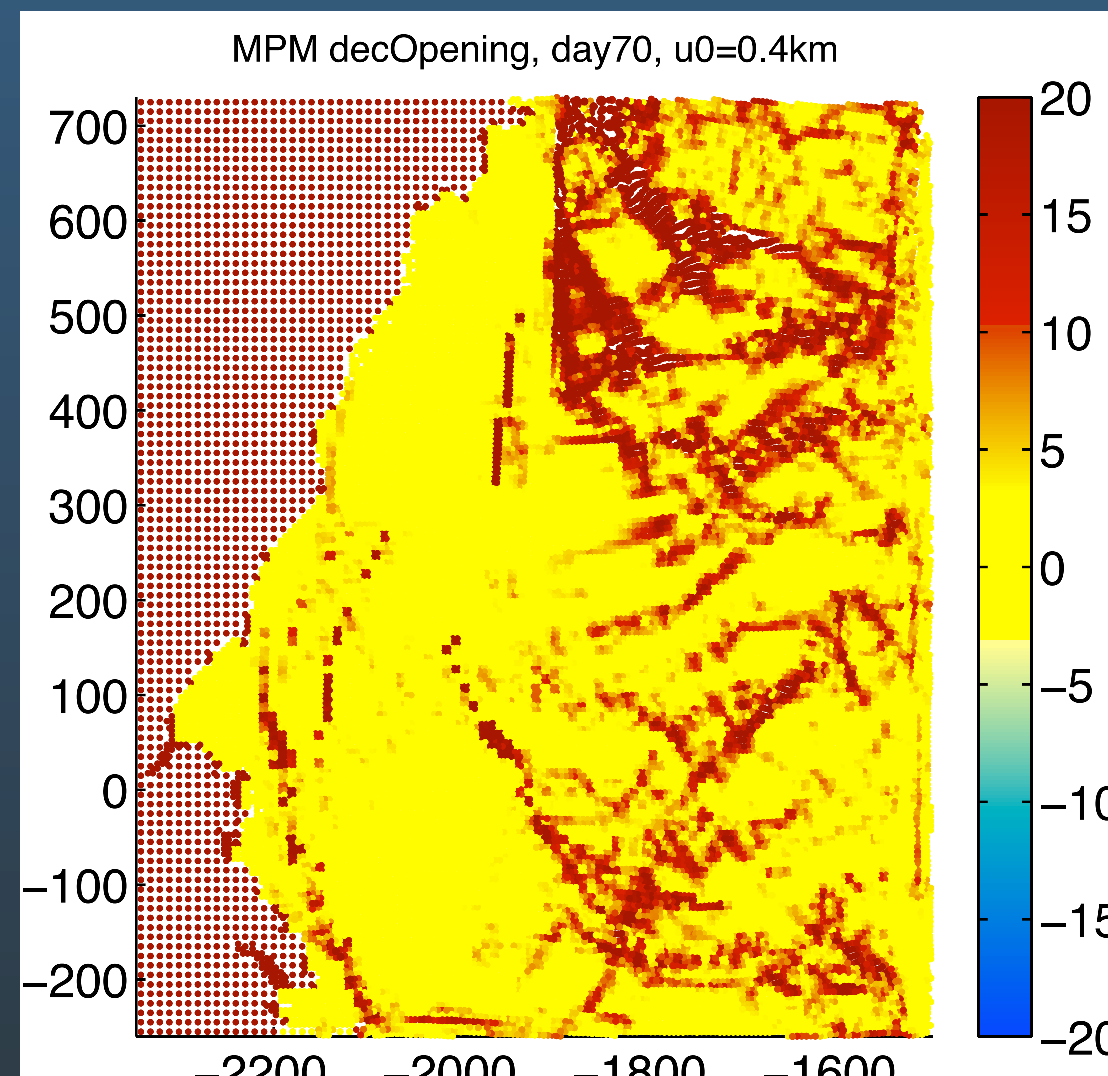
Fracture Patterns in the Beaufort

day 70



Observation



Simulation

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Notes

Calculations were done

- without tuning parameters

- with crude initial guess
- with no refreezing of leads

- with errors from preprocessing satellite data

Summary

Features of elastic-decohesive model:

- Stress state at which leads initiate
- Orientation of lead at initiation
- Evolution of lead (softening)
- Existing material weakness
- Implemented in plasticity framework

Work in progress:

- Initial conditions
- Freezing model
- Coupling to ocean
- Metrics